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More C uptake during the dry season? The case of a semi-arid agro-silvo-pastoral ecosystem dominated by Faidherbia albida, a tree with reverse phenology (Senegal)

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Agro-silvo-pastoralism is a highly representative Land Use in Africa, often presented as a strategical option for ecological intensification of cropping systems towards food security and sovereignty.

We set up a new long-term observatory (“Faidherbia-Flux”) to monitor and model microclimate, energy and C balance in Niakhar (central Senegal, rainfall ~ 500 mm), dominated by the multipurpose tree Faidherbia albida (12.5 m high; 7 tree ha^{-1}; 5% canopy cover). Faidherbia is an attractive agroforestry tree species in order to partition fluxes, given that it is on leaf during the dry season (October-June) and defoliated during the wet season, just when crops take over. Pearl-millet and groundnut crops were conducted during the wet season, following annual rotation in a complex mixed mosaic of ca. 1 ha fields.

Early 2018, we installed an eddy-covariance (EC) tower above the whole mosaic (EC1: 20 m high). A second EC system was displayed above the crop (EC2: 4.5 m if pearl-millet, 2.5 m if groundnut) in order to partition ecosystem EC fluxes between tree layer and crop+soil layers. Sap-flow was monitored from April 2019 onwards in 5 faidherbia trees (37 sensors).

The ecosystem displayed moderate but significant daily CO_2 and H_2O fluxes during the dry season, when faidherbia (low canopy cover) was in leaf and the soil was evaporating. At the onset of the rainy season, the soil bursted a large amount of CO_2. Just after the growth of pearl-millet in 2018, CO_2 uptake by photosynthesis increased dramatically. However, this was largely compensated by

high ecosystem respiration. Surprisingly in 2019, although the crop was turned to groundnut, the fluxes behaved pretty much the same as with pearl millet in 2018: comparing annual balances between 2018 and 2019 we obtained [454, 513] for rainfall (P: mm yr^{-1}), [3500, 3486] for potential evapotranspiration (ETo: mm yr^{-1}), [0.13, 0.15] for P/ETo, [470, 497] for actual evapotranspiration (E: mm yr^{-1}), [2809, 2785] for net radiation (R_n: MJ m^{-2} yr^{-1}), [1686, 1645] for sensible heat flux (H: MJ m^{-2} yr^{-1}), [-3.2, -2.8] for net ecosystem exchange of C (NEE: tC ha^{-1} yr^{-1}), [-11.8, -11.1] for gross primary productivity (GPP: tC ha^{-1} yr^{-1}) and [8.6, 8.3] for ecosystem respiration (R_e: tC ha^{-1} yr^{-1}). The energy balance (R_n-H-LE) was nearly nil indicating that the EC system behaved reasonably. E was very close to P, indicating that little or no water would recharge the deep soil layers.

Now comparing the dry (2/3 of the year) and wet (1/3) seasons: surprisingly, NEE was more effective during the dry season [-3.9, -1.7]. This was the result of R_e being much lower on a daily basis as well as cumulated over the entire seasons [57, 84], whereas GPP was similar [-10.8, -12.1].

We found a good match between E measured above the whole ecosystem (EC1), and the sum of tree transpiration (T, measured by sapflow) + E measured just above crops + soil (EC2) throughout the wet and dry seasons.

The “Faidherbia-Flux” observatory is registered in FLUXNET as SN-Nkr and is widely open for collaboration.